DECLARATION

I, Masato Sasaki, c/o Fukami Patent Office, Nakanoshima Central Tower, 22nd Floor, 2-7, Nakanoshima 2-chome, Kita-ku, Osaka-shi, Osaka, Japan, declare:

that I know well both the Japanese and English languages;

that to the best of my knowledge and belief the English translation attached hereto is a true and correct translation of Japanese Patent Application No. 2004-004355, filed on January 9, 2004;

that all statements made of my own knowledge are true;

that all statements made on information and belief are believed to be true; and

that the statements are made with the knowledge that willful false statements and the like are punishable by fine or imprisonment, or both, under 18 USC 1001.

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[Document Name] Scope of Claims for Patent

[Claim 1]

A thrust needle roller bearing having a washer formed of a thin steel plate and a needle roller, wherein at least said washer has a nitrogen enriched layer at a surface layer portion, amount of retained austenite in said surface layer portion is at least 5 volume % and at most 25 volume %, and austenite grain size number of said surface layer portion is 11 or higher.

[Claim 2]

The thrust needle roller bearing according to claim 1, wherein nitrogen content of said surface layer portion is in the range of 0.1 mass % to 0.7 mass %.

[Document Name] Specification

[Title of the Invention] Thrust Needle Roller Bearing

[Technical Field]

[0001]

The present invention relates to a thrust needle roller bearing and, more specifically, to a thrust needle roller bearing for a car air-conditioner compressor and for automatic transmission.

[Background Art]

[0002]

A thrust needle roller bearing consists of needle rollers, a cage and a washer, in which the needle rollers are in line-contact with the washer. Therefore, the bearing advantageously attains high load carrying capacity and high rigidity, for its small projection area. Therefore, a thrust needle roller bearing is suitable as a bearing used under severe conditions of low viscosity lubrication or high-speed rotation, and it is used for a compressor for car air-conditioner and an automatic transmission.

[0003]

Such a thrust needle roller bearing is disclosed, for example, in Patent Document 1 (Japanese Patent Laying-Open No. 2002-70872).

[0004]

Oil used in a compressor for a car air-conditioner has low viscosity, and the amount of oil is made small in order to improve compressor performance (cooling performance). As the bearing is used under such severe, low viscosity lubrication conditions, the bearing might possibly fail at an early stage because of surface damage, such as surface-originated flaking, if there is much differential slip at the roller.

[0005]

Conventionally, auto manufacturers and manufacturers of automatic transmissions sometimes use oil with an additive, in view of energy saving. The oil with such an additive has lower lubrication performance on the bearing than common oil,

and therefore, improvement of existing thrust bearings involving much differential slip at the rollers has been desired, from the viewpoint of surface damage such as surface-originated flaking.

[0006]

There is a tendency that compressors for car air-conditioner and automatic transmissions are used under higher load, and therefore, improvement of existing bearings is also desirable from the viewpoint of subsurface-originated flaking caused by common load-dependent rolling contact fatigue.

[0007]

Therefore, a bearing of long life that is resistant to an early failure caused by surface damage such as surface-originated flaking and resistant also to subsurface-originated flaking caused by common load-dependent rolling contact fatigue is desired.

[Patent Document 1] Japanese Patent Laying-Open No. 2002-70872

[Disclosure of the Invention]

[Problems to be Solved by the Invention]

[0008]

Conventionally, as a material for the washer of a thrust needle roller bearing, readily processable and available steel plate and steel tape material that allows press-processing, including low carbon structural steel, cold-rolled steel plate, steel tape, medium carbon steel or bearing steel has been used. When low carbon structural steel, cold-rolled steel plate or steel tape is used, carburization or carbonitriding process is performed as heat treatment of the washer, and when medium carbon steel or bearing steel is used, bright quenching or induction hardening is performed.

[0009]

Bearing steel is used as the material of the roller of a conventional thrust needle roller bearing, and bright quenching or induction hardening is performed as heat treatment.

[0010]

In a thrust needle roller bearing, heat caused by differential slip at the roller may induce damage such as surface-originated flaking. Enforcement of the washer against the surface damage including the surface-originated flaking is desired.

[0011]

Further, under heavy load conditions, subsurface-originated flaking also occurs because of common load-dependent rolling contact fatigue, and longer life is desired.

[0012]

The present invention was made in view of the foregoing and an object is to provide a long life thrust needle roller bearing having at least washer characteristic changed to be resistant to an early failure caused by surface damage such as surface-originated flaking and resistant also to common load-dependent rolling contact fatigue.

[Means for Solving the Problems]

[0013]

The present invention provides a thrust needle roller bearing having a washer formed of a thin steel plate and needle rollers, wherein at least the washer has a nitrogen enriched layer at a surface layer portion, amount of retained austenite in the surface layer portion is at least 5 volume % and at most 25 volume %, and austenite grain size number of the surface layer portion is 11 or higher.

[0014]

In the thrust needle roller bearing described above, preferably, nitrogen content of the surface layer portion is in the range of 0.1 mass % to 0.7 mass %.

[Effects of the Invention]

[0015]

In the thrust needle roller bearing in accordance with the present invention, the washer material is adapted to have fine crystal grain size and high heat resistance, and therefore, life defined by surface-originated flaking (surface damage such as peeling and smearing) and life defined by subsurface-originated flaking can both be improved.

[0016]

Specifically, by devising and adjusting processing and heat treatment of the material such as bearing steel and medium carbon steel, a carbonitrided texture (nitrogen enriched layer) reliably having autstenite grain size number of 11 or higher can be obtained. This texture significantly increases resistance to generation and development of cracks. As a result, heat generation at a surface layer caused by slipping or surface cracks caused by tangential force can be suppressed. Further, the inventors have found that significantly longer life can be attained as regards cracks caused by subsurface-originated flaking.

[0017]

Considering the surface damage such as the surface-originated flaking, it is particularly essential that a heat-resistant, nitrogen enriched layer having fine carbide deposited at the surface layer portion is formed. In the present invention, a nitrogen enriched layer is formed, and in addition, at least 5 volume % of retained austenite exists at the surface layer portion and the austenite at the surface layer portion is as fine as to have austenite grain size number of 11 or higher. Thus, surface damage such as surface-originated flaking can be suppressed.

[0018]

The retained austenite existing in the nitrogen enriched layer at the surface layer portion is a factor that decreases surface hardness. Therefore, it is necessary to decrease the amount of retained austenite than a carbonitrided article, through quenching after carbonitriding process, by re-heating to a temperature lower than the temperature of carbonitriding process. In the present invention, the retained austenite at the surface layer portion is reduced to 25 volume % or lower, and therefore, decrease in surface hardness can be suppressed.

[0019]

With the above-described micro-texture as a basic component, further processing or heat treatment is performed to exert compressive stress on the surface layer described above, to further increase hardness, whereby longer life can be attained.

As the processing or heat treatment, a technique such as (b1) shot peening, (b2) barreling, (b3) rolling, (b4) carburization + carbonitriding, (b5) carbonitriding + sub zero treatment or (b6) carbonitriding + secondary quenching + sub zero treatment may be applied by itself, or combination of techniques (b1) to (b6) may be applied.

[0020]

At least one of the washer and the roller may be subjected to the carbonitriding process at A_1 transformation point or higher, cooled to a temperature lower than the A_1 transformation point, thereafter heated to a quenching temperature lower than the temperature of carbonitriding process, and then quenched from that quenching temperature.

[0021]

In the process of cooling to a temperature lower than the A_1 transformation point after carbonitriding at the carbonitriding temperature, the temperature may be lowered to room temperature by oil quenching, or cooled to a temperature at which austenite transformation is completed at least to a prescribed value. By the manufacturing method described above, a metal texture having a nitrogen enriched layer, fine austenite grains and containing appropriate amount of retained austenite can be obtained. Consequently, life defined by surface-originated flaking and life defined by subsurface-originated flaking can both be improved. Further, a thrust needle roller bearing can be provided, of which dimensional variation with aging is suppressed.

[0022]

As described above, the nitrogen enriched layer is formed by carbonitriding process, and the nitrogen enriched layer may or may not be carbon-enriched.

[0023]

In such a micro-texture, very fine austenite crystal grains can be obtained, as it is once cooled after carbonitriding process and quenched from a quenching temperature lower than the temperature of carbonitriding process. The process of heating to the quenching temperature lower than the temperature of carbonitriding process and

quenching is sometimes referred to as secondary quenching or final quenching, in view of the order of processing.

[0024]

The quenching temperature mentioned above may be in a temperature range where carbide and/or nitride and austenite phase co-exist at least in the surface layer portion of the carbonitrided steel.

[0025]

As the heating temperature at the time of quenching is lower than the heating temperature of carbonitriding process, the amount of carbide and/or nitride not-yet-absorbed at the surface layer portion subject to the effect of carbonitriding process is increased than in the carbonitriding process. Therefore, when the quenching temperature is in the above-described co-existing temperature range, the ratio of not-yet-absorbed carbide/nitride at the quenching temperature is increased than in the carbonitriding process, and the ratio of austenite amount decreases. Further, it can be seen from the binary phase diagram of iron-carbon, in the region where carbide (cementite) and austenite co-exist, that concentration of carbon contained as solid solution in austenite decreases as the quenching temperature decreases. The steel used for a bearing has low content of other alloy element such as Si (silicon) or Mn (manganese) and, therefore, it is possible with sufficiently high accuracy to discuss temperature ranges and generated layers, using the iron-carbon binary phase diagram. Further, similar to carbon, nitrogen is contained as interstitial solid solution in iron, and generates nitride with iron similar to cementite in a prescribed temperature range. Therefore, it can be regarded as the same as carbon, in approximation.

[0026]

When heated to the quenching temperature, there is a large amount of carbide and/or nitride that is not yet absorbed and prevents growth of austenite grains, and hence, the austenite grains come to be very fine. Further, the texture transformed by quenching from austenite to martensite has slightly lower carbon concentration when

subjected to the heat treatment described above, and therefore, the texture comes to have slightly higher toughness than the texture quenched from the carbonitriding temperature. Specifically, the quenched texture comes to have (c1) not-yet-absorbed carbide and/or nitride of larger amount than the conventional example and (c2) carbon concentration lower than the conventional example.

[0027]

The quenching temperature mentioned above may be set to 780°C to 830°C. This temperature range may be applied to almost every steel material, so that management of quenching temperature is simplified.

[0028]

Further, at least one of the washer and roller described above may be subjected to cold working such as pressing, prior to the carbonitriding process.

[0029]

By performing such cold working, nucleation density of austenite grains at the time of heat treatment increases, and very fine texture can be obtained.

[0030]

Further, to at least one of the washer and the roller described above, compressive stress of at least 500 MPa may be applied.

[0031]

As already described, with the above-described micro-texture as a basic component, further processing or heat treatment may be performed to exert compressive stress on the surface layer described above, whereby longer life can be attained.

[0032]

In the present specification, austenite grain size number refers to the grain size number of austenite defined by the method of austenite grain size determination in accordance with JIS G 0551.

[0033]

In the present specification, the austenite grain refers to austenite crystal grain

that is phase-transformed during quenching, and refers to the one remaining even after transformation by cooling to martensite, as the past history.

[0034]

The austenite crystal grains should have grain boundary that can be observed by performing a process such as etching to expose the grain boundary on a metallographic sample of the object member. The grains are also referred to as old austenite grains, meaning the grain boundary at a heated time point immediately before low-temperature quenching. As to the measurement, an average value of grain numbers of JIS standard may be converted as an equivalent to the average grain diameter, or a section method or the like may be used, in which an average of distances at which straight lines in random direction overlapped on the metallographic sample meet the grain boundary is calculated and multiplied by a correction coefficient to obtain the two-dimensional to three-dimensional distance.

[0035]

The retained austenite is measured using various X-ray diffraction methods, in which, by way of example, diffraction intensity of appropriate Miller indices of the austenite phase is found, and compared with diffraction intensity of appropriate Miller indices of the ferrite phase. At this time, height of diffraction peak may be used, or area of diffraction peak may be used. Alternatively, it can be measured utilizing the fact that the austenite phase is non-magnetic and the ferrite phase is ferromagnetic, by finding magnetizing force using a magnetic balance. It can also be measured easily by a commercially available measuring device.

[0036]

At the time of low temperature quenching, the austenite phase transforms to martensite and the like. The retained austenite refers to austenite left untransformed after the temperature is cooled to the room temperature, between adjacent martensite bundles or the like that transform along different crystal faces. Therefore, it is not directly related to the austenite crystal grains of which range of average grain size is

limited as described above.

[0037]

It is not effective when the nitrogen content at the surface layer portion is smaller than 0.1 mass %, and rolling contact fatigue life decreases particularly in the presence of foreign matters. When the nitrogen content is larger than 0.7 mass %, pores referred to as voids are generated, or the amount of retained austenite becomes too large to attain sufficient hardness, so that the life becomes shorter. The nitrogen content of the nitrogen enriched layer formed in the washer is represented by a value at the surface layer of 50 μm from the surface of washer after grinding, which may be measured by an EPMA (Electron Probe Micro-Analysis).

[Best Modes for Carrying Out the Invention]

[0038]

Embodiments of the present invention will be described with reference to the figures.

[0039]

Fig. 1 is a schematic cross sectional view showing a structure of a thrust needle roller bearing in accordance with Embodiment 1 of the present invention. Referring to Fig. 1, the thrust needle roller bearing 10A has a pair of washers 1, 1, formed of thin steel plates, a plurality of needle rollers rolling between the pair of washers 1, 1, and an annular cage 3 holding the plurality of needle rollers 2 at a prescribed pitch along the circumferential direction. Washer 1 has a through hole 1a at the central portion, for inserting a shaft or the like.

[0040]

At least washer 1 of thrust needle roller bearing 10A has a nitrogen enriched layer at a surface layer portion, the amount of retained austenite at the surface layer portion is at least 5 volume % and at most 25 volume %, and the austenite grain size number at the surface layer portion is 11 or larger. Preferably, nitrogen concentration at the surface layer portion is at least 0.05 mass % and at most 0.4 mass %.

[0041]

Alternatively, not only washer 1 but also needle rollers 2 or cage 3 may have a nitrogen enriched layer at the surface layer portion, the amount of retained austenite at the surface layer portion may be at least 5 volume % and at most 25 volume %, and the austenite grain size number at the surface layer portion may be 11 or larger. Nitrogen concentration at the surface layer portion may be at least 0.05 mass % and at most 0.4 mass %.

[0042]

Though a structure in which the needle rollers are arranged in a single row has been described above, the needle rollers may be arranged in a plurality of rows, as shown in Fig. 2.

[0043]

Referring to Fig. 2, the thrust needle roller bearing 10B has needle rollers 2 arranged in a plurality of rows, including needle rollers 2a on the inner diameter side and needle rollers 2b on the outer diameter side. Here, cage 3 is preferably formed by two annular plate members 3a and 3b overlapped to be in contact with each other. Preferably, annular member 3a has an end portion on the inner diameter side bent and crimped to the side of annular member 3b, and annular member 3b has an end portion on the outer diameter side bent and crimped to the side of annular member 3a. In this manner, two annular members 3a and 3b can be fixed by crimping and firmly integrated.

[0044]

Though lengths L1 and L2 of needle rollers 2a and 2b arranged in a plurality of rows are the same in this example, the length may be selected to $L1 \leq L2$ or $L2 \leq L1$, dependent on the conditions of use. It is preferred to increase load carrying capacity on the outer diameter side by making the length L2 of the needle roller 2b on the outer diameter side longer, for example, 1.2 times longer, than the length L1 of the needle roller 2a on the inner diameter side.

[0045]

Except for the point described above, the structure of thrust needle roller bearing 10B is almost the same as that of thrust needle roller bearing 10A described above and, therefore, the same members are denoted by the same reference characters and description thereof will not be repeated.

[0046]

Next, heat treatment including carbonitriding process performed on at least one bearing component of washer 1, needle roller 2 and cage 3 of each of thrust needle roller bearings 10A and 10B in accordance with the present embodiment will be described.

[0047]

Figs. 3 and 4 show the method of heat treatment for forming the thrust needle roller bearing in accordance with the present invention. Fig. 3 shows a pattern of heat treatment representing a method involving primary and secondary quenching. Fig. 4 shows a pattern of heat treatment in which the material is cooled to a temperature lower than A_1 transformation point during quenching and thereafter re-heated for final quenching. Both are examples of heat treatment for the thrust needle roller bearing of the present invention.

[0048]

Referring to Fig. 3, first, steel for a bearing component is heated to a carbonitriding temperature (845°C) not lower than the A_1 transformation point, and at this temperature, carbonitriding process is performed on the steel for the bearing component. At the process temperature T_1, carbon and nitrogen are diffused to the steel base, and carbon is sufficiently absorbed in steel. Thereafter, the steel for bearing component is subjected to oil quenching from the process temperature T_1 to a temperature lower than A_1 transformation point. Thereafter, tempering at 230°C is performed. The tempering may be omitted.

[0049]

Thereafter, the steel for bearing component is heated again to a temperature (for example, 800°C), which is not lower than the A_1 transformation point and lower than

the carbonitriding temperature described above, and kept at the temperature for a process T_2, subjected to oil quenching from the process temperature T_2 and cooled to a temperature lower than the A_1 transformation point. Then, tempering is performed at 230°C.

[0050]

Referring to Fig. 4, first, steel for a bearing component is heated to a carbonitriding temperature (845°C) not lower than the A_1 transformation point, and at this temperature, carbonitriding process is performed on the steel for the bearing component. At the process temperature T_1, carbon and nitrogen are diffused to the steel base, and carbon is sufficiently absorbed in steel. Thereafter, the steel for bearing component is not subjected to quenching but cooled to a temperature lower than the A_1 transformation point. Thereafter, the steel for bearing component is heated again to a temperature (for example, 800°C), which is not lower than the A_1 transformation point and lower than the carbonitriding temperature described above, and kept at the temperature for a process T_2, subjected to oil quenching from the process temperature T_2 and cooled to a temperature lower than the A_1 transformation point. Then, tempering is performed at 230°C.

[0051]

By the carbonitriding process described above, a nitrogen enriched layer, which is the "carbonitrided layer," is formed at the surface layer portion of the steel for bearing component. In the carbonitriding process, steel as the material has high carbon concentration, and therefore, sometimes carbon does not readily enter the surface of steel from common carbonitriding atmosphere. In steel having high carbon concentration (of about 1 mass %), a carburized layer of higher carbon concentration may or may not be generated. On the other hand, though it depends on Cr (chromium) concentration, nitrogen concentration is as low as about 0.020 mass% in typical steel. Therefore, a nitrogen enriched layer is definitely formed regardless of the carbon concentration of material steel. It is needless to say that the nitrogen enriched layer

may also be enriched with carbon.

[0052]

As compared with common quenching (that is, one quenching following carbonitriding process), the heat treatment described above is effective against an early failure caused by surface damage such as surface-originated flaking and also effective against subsurface-originated flaking caused by common rolling contact fatigue dependent on load, while carbonitriding of the surface layer is attained. Therefore, the treatment enables longer life of the thrust needle roller bearing.

[0053]

Fig. 5(a) shows austenite grain size of the bearing steel that has been subjected to the heat treatment pattern shown in Fig. 3. For comparison, Fig. 5(b) shows austenite grain size of the bearing steel that has been subjected to conventional heat treatment. Figs. 6(a) and 6(b) illustrate austenite grain size corresponding to Figs. 5(a) and 5(b). From these textures showing the austenite grain size, it can be seen that the conventional austenite grain size has JIS (Japanese Industrial Standard) grain size number 10, whereas the heat treatment in accordance with the present invention provides fine grains of number 12. The average grain diameter of Fig. 5(a) measured by the section method was 5.6 μm.

[0054]

Next, a compressor for a car air-conditioner using the thrust needle roller bearing 10B (Fig. 2) in accordance with the present embodiment will be described.

[0055]

Fig. 7 is a schematic cross sectional view showing a structure of a compressor using the thrust needle roller bearing in accordance with Embodiment 1 of the present invention. Referring to Fig. 7, as the compressor, a double-sided swash plate compressor 100 is shown. Swash compressor 100 is structured such that by the rotation of a swash plate 103 fixed on a main shaft 104, a piston 107 reciprocates with a shoe 109 sliding on swash plate 103.

[0056]

In a housing 102, main shaft 104 having swash plate 103 fixed thereon is rotatably supported by means of a radial bearing 105. In housing 102, a plurality of cylinder bores 106 are formed at equally spaced positions in the circumferential direction, and a double-ended piston 107 is slidably contained in each bore 106. At the central portion of each piston 107, a recessed portion 108 is formed to cross over the circumferential portion of swash plate 103, and on axially opposing surfaces of recessed portion 108, spherical seats are formed, on which a spherical or semi-spherical shoe 109 is seated. Shoe 109 is interposed between swash plate 103 and piston 107, and functions to convert rotational motion of swash plate 103 smooth to reciprocating motion of piston 107.

[0057]

Swash plate 103 is fixed on main shaft 104 and rotates with main shaft 104. As described above, swash plate 103 functions to cause reciprocating motion of piston 107. Therefore, thrust load generates along the axial direction of main shaft 104. Therefore, thrust needle roller bearing 10B is used as a support structure to receive the thrust load. As described above, thrust needle roller bearing 10B has a pair of washers 1, 1, needle rollers 2a, 2b arranged in a plurality of rows, and a cage 3. One of the pair of washers 1 is mounted on swash plate 103 and the other of the pair of washers 1 is mounted on the side of housing 102.

[0058]

In the embodiment above, a double-sided swash plate compressor has been described as the compressor. The thrust needle roller bearing of the present invention, however, is also applicable to other types of swash plate compressors or scroll type compressors. The swash plate compressors of the other type may include a one-sided swash plate compressor and a variable capacity, one-sided swash plate compressor.

[0059]

In a one-sided swash plate compressor 200, thrust needle roller bearing 10B of a

plurality of rows in accordance with the present embodiment is arranged as a support structure to receive the thrust load, between a coupling member 211 and a housing 202 and between coupling member 211 and a swash plate 203, as shown in Fig. 8. Coupling member 211 is a member for coupling swash plate 203 with piston 207. In compressor 200, swash plate 203 rotates with the rotation of main shaft 204, and coupling member 211 swings accordingly, so that through a piston rod 215, piston 207 reciprocates in the cylinder.

[0060]

In a one-sided swash plate, variable capacity compressor 300, thrust needle roller bearing 10B of a plurality of rows in accordance with the present embodiment is arranged as a support structure to receive the thrust load, between a journal 303 corresponding to the swash plate and a piston support 312, as shown in Fig. 9. Further, thrust needle roller bearing 10B of a plurality of rows in accordance with the present embodiment is arranged as a support structure to receive the thrust load, between a housing 302 and a sleeve 314 of a main shaft 304.

[0061]

In compressor 300, journal 303 rotates with the rotation of main shaft 304, and piston support 312 swings accordingly, so that through a piston rod 315, piston 307 reciprocates in the cylinder. In compressor 300, the angle of inclination of journal 303 can be changed by sliding sleeve 314 coupled to drive pin 313 in the axial direction with respect to the main shaft 304, whereby the capacity can be changed.

[0062]

Next, an automatic transmission using thrust needle roller bearing 10B (Fig. 2) of the present embodiment will be described.

[0063]

Fig. 10 is a schematic cross sectional view showing a structure of an automatic transmission using the thrust needle roller bearing in accordance with an embodiment of the present invention. Referring to Fig. 10, an automatic transmission typically consists

of a torque converter 400 and a planetary gear mechanism (not shown).

[0064]

Torque converter 400 mainly has an impeller 401, a stator 402 and a turbine 403. The thrust needle roller bearing 10B in accordance with the present embodiment as a support structure receiving the thrust load of the transmission is mounted, for example, between impeller 401 and stator 402, and between stator 402 and turbine 403.

[0065]

In torque converter 400, impeller 401 coupled to an output shaft of an engine and turbine 403 coupled to an input shaft of the transmission are arranged opposite to each other. Further, stator 402 is attached to a stator shaft fixed on a casing, by means of a one-directional clutch 404. When a liquid under reflux between an impeller blade 401a and a turbine blade 403a each formed to have a bowl shape is returned from the side of turbine 403 to the side of impeller 401 on the inner diameter side, stator 402 changes the direction of liquid flow to exert a forward rotational force to impeller 401, so as to amplify transmission torque.

[0066]

Thrust needle roller bearing 10B between impeller 401 and stator 402 has a pair of washers 1, 1, needle rollers 2a, 2b and a cage 3. One of the pair of washers 1 is mounted on turbine hub 403b, and the other one of the pair of washers 1 is mounted on the side of stator 402.

[0068]

Though a plurality of thrust needle roller bearings 10B are provided on a car air-conditioner compressor or an automatic transmission in the examples described above, a single thrust needle roller bearing 10A shown in Fig. 1 may be provided in place of the plurality of thrust needle roller bearings 10B.

[Examples]

[0069]

Examples of the present invention will be described in the following.

[0070]

Rollers and washers (having the thickness of at most 3 mm) formed of press-processable steel plates and steel tapes of SUJ2 material (JIS: high carbon chromium bearing steel material), SCM415M (JIS: chromium-molybdenum steel) and S70C (JIS: carbon steel material for machine structural purpose) were prepared. Various heat treatments were performed on the washers and rollers. The heat treatments included heat treatments of heating patterns shown in Figs. 3 and 4 (special heat treatment), carbonitriding process, quenching (quench-hardening, high temperature quench-hardening, double quench-hardening) and carburizing process.

[0071]

In the special heat treatment, the objects were kept in a mixed gas atmosphere of an RX gas and an ammonia gas, at 840°C for a prescribed time period for carbonitriding, subjected to primary quenching from that temperature, and tempered at 230°C. Thereafter, the temperature was again increased to 800°C, which is lower than the carbonitriding temperature, the components were kept at that temperature for a prescribed time period, subjected to secondary quenching, and then tempered at 230°C.

[0072]

In the carbonitriding process, the objects were kept at 840°C for a prescribed time period for carbonitriding, thereafter quenched from that temperature and tempered at 230°C.

[0073]

In the carbonitriding process + quench-hardening process, the objects were kept at 840°C for a prescribed time period for carbonitriding, thereafter quenched from that temperature and tempered at 230°C. Then, the temperature was again increased to 840°C, the components were kept at that temperature for a prescribed time period, subjected to quenching from that temperature, and tempered at 230°C.

[0074]

In the carburizing process, the objects were kept at 850°C for a prescribed time

period for carburization, subjected to quenching from that temperature, and then tempered at 230°C.

[0075]

In the quench-hardening process, the objects were kept at 850°C for a prescribed time period, subjected to quenching from that temperature, and then tempered at 230°C.

[0076]

In the high temperature quench-hardening process, the objects were kept at 880°C for a prescribed time period, subjected to quenching from that temperature, and then tempered at 230°C.

[0077]

In the double quench-hardening process, the objects were kept at 840°C for a prescribed time period, subjected to primary quenching from that temperature, and then tempered at 230°C. Then, the temperature was again increased to 840°C, the objects were kept at that temperature for a prescribed time period, subjected to secondary quenching from that temperature, and tempered at 230°C.

[0078]

Crystal grain size numbers, amount of retained austenite and nitrogen content at the surface layer of the washers subjected to the processes above are as shown in Table 1.

[0079]

Crystal grain size was measured by the method of austenite grain size determination in accordance with JIS G 0551. Average values among ten test samples formed under the same conditions were found.

[0080]

The amount of retained austenite was measured by X-ray diffraction method, at a depth of 0.05 mm from the surface at four positions of the washer surface. Further, average values among ten test samples (10 samples × 4 positions) formed under the same conditions were found.

[0081]

The nitrogen content at the surface layer portion of washers was measured by EPMA analysis, by cutting the washers vertical to the washer surface. Average values of five samples formed under the same conditions were found.

[0082]

[Table 1]

Test Sample Materials

	Materials and heat treatments of washers	Grain size (No.)	Amount of retained austenite (vol%)	Nitrogen content of surface layer (mass%)
Present invention	SUJ2 special heat treatment	12.5	8.2	0.25
	SCM415M special heat treatment	12.0	22.2	0.29
	S70C special heat treatment	11.5	15.4	0.27
Comparative Example	SUJ2 carbonitriding	10.5	28	0.28
	SCM415M carbonitriding	10.0	32.4	0.33
	SCM415M carbonitriding + quench-hardening	11.0	27.6	0.31
	S70C carbonitriding	9.5	26.6	0.3
	SUJ2 quench-hardening	10.0	4.2	0
	SCM415M carburizing	9.5	28.2	0
	S70C quench-hardening	9.5	3.8	0
	SUJ2 high temp. quench-hardening	9.0	10.8	0
	SUJ2 double quench-hardening	11.5	4.0	0

[0083]

As can be seen from the results shown in Table 1, in all test samples of washers subjected to special heat treatment formed of SUJ2, SCM415M and S70C, a nitrogen enriched layer was observed at the surface layer portion, the grain size number of austenite at the surface layer portion was 11 or higher, amount of retained austenite was at least 5 volume % and at most 25 volume %, and nitrogen content at the surface layer portion was at least 0.1 mass % and at most 0.7 mass %.

[0084]

The test samples subjected to heat treatments other than the special heat treatment cannot attain one of or both of austenite grain size number of 11 or higher and amount of retained austenite of at least 5 volume % and at most 25 volume %.

[0085]

Then, thrust needle roller bearings were formed by combining each of the washers described above with rollers, and life test of the thrust needle roller bearings was conducted. The conditions of life test are as shown in Table 2, and the test results are as shown in Table 3.

[0086]

[Table 2]

Test Conditions

Load	4000N
Speed of Rotation	8000 r/min
Lubrication	Mission oil circulating lubrication, natural warming

[0087]

[Table 3]

Example	No.	Characteristics	Life ratio (L10)
Present invention	1	washer, roller: SUJ2 special heat treatment	17.2
	2	washer: SUJ2 special heat treatment roller: SUJ2 carbonitriding	16.5
	3	washer: SCM415M special heat treatment roller: SUJ2 special heat treatment	10.8
	4	washer: SCM415M special heat treatment roller: SUJ2 carbonitriding	8.5
	5	washer: S70C special heat treatment roller: SUJ2 special heat treatment	14.2
	6	washer: S70C special heat treatment roller: SUJ2 carbonitriding	13.1
Comparative Example	7	washer: SCM415M carbonitriding roller: SUJ2 carbonitriding	3.0
	8	washer: SCM415M carbonitriding + quench-hardening roller: SUJ2 carbonitriding	3.3
	9	washer: SCM415M carbonitriding roller: SUJ2 quench-hardening	1.5
	10	washer, roller: SUJ2 carbonitriding	4.2
	11	washer: S70C carbonitriding roller: SUJ2 carbonitriding	3.4
	12	washer: SCM415M carburizing roller: SUJ2 carbonitriding	1.0
	13	washer: SCM415M carburizing roller: SUJ2 quench-hardening	0.5
	14	washer: SUJ2 quench-hardening roller: SUJ2 carbonitriding	0.9
	15	washer: SUJ2 high temperature quench-hardening roller: SUJ2 carbonitriding	1.0
	16	washer: SUJ2 double quench-hardening roller: SUJ2 carbonitriding	0.9
	17	washer: SUJ2 quench-hardening roller: SUJ2 quench-hardening	0.4
	18	washer: S70C quench-hardening roller: SUJ2 quench-hardening	0.4

* Special heat treatment: developed heat treatment

[0088]

As can be seen from the result of Table 3, the thrust needle roller bearings having washers subjected to the special heat treatment have improved L10 life (number of loaded operation at which 90 % of sample thrust needle roller bearings could be used

without breakage), and have longer life, as compared with thrust needle roller bearings having washers not subjected to the special heat treatment. Where washers and rollers are of the same material, it can be seen that L10 life can further be improved when not only washers but rollers are subjected to the special heat treatment.

[0089]

The embodiments as have been described here are mere examples and should not be interpreted as restrictive. The scope of the present invention is determined by each of the claims with appropriate consideration of the written description of the embodiments and embraces modifications within the meaning of, and equivalent to, the languages in the claims.

[Industrial Applicability]

[0090]

The present invention is advantageously applied to a thrust needle roller bearing for a compressor of a car air-conditioner and an automatic transmission.

[Brief Description of the Drawings]

[Fig. 1] A schematic cross sectional view showing a structure of a thrust needle roller bearing in accordance with an embodiment of the present invention.

[Fig. 2] A schematic cross sectional view showing a structure of a thrust needle roller bearing having rollers arranged in a plurality of rows, as another embodiment of the present invention.

[Fig. 3] An illustration of a method of heat treatment of the thrust needle roller bearing in accordance with the present invention.

[Fig. 4] An illustration of a modification of the method of heat treatment of the thrust needle roller bearing in accordance with the present invention.

[Fig. 5] Views showing micro-texture, particularly austenite grains of the bearing component, in which (a) shows bearing component of the present invention, and (b) shows a conventional bearing component.

[Fig. 6] Illustration (a) corresponding to Fig. 5(a) showing austenite grain

boundaries, and illustration (b) corresponding to Fig. 5(b) showing austenite grain boundaries.

[Fig. 7] A schematic cross sectional view showing a structure of a double-sided swash plate compressor.

[Fig. 8] A schematic cross sectional view showing a structure of a one-sided swash plate compressor.

[Fig. 9] A schematic cross sectional view showing a structure of a variable capacity, one-sided swash plate compressor.

[Fig. 10] A schematic cross sectional view showing a structure of a torque converter portion of an automatic transmission.

[Description of the Reference Characters]

[0092]

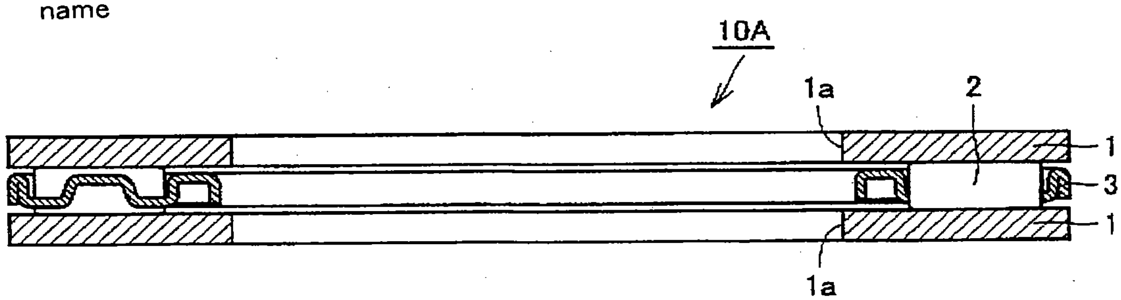
1 washer, 1a through hole, 2, 2a, 2b needle rollers, 3 cage, 3a, 3b annular members, 10A, 10B thrust needle roller bearings, 100 double-sided swash plate compressor, 102 housing, 103 swash plate, 104 main shaft, 105 radial bearing, 106 cylinder bore, 107 piston, 108 recessed portion, 109 shoe, 200 one-sided swash plate compressor, 202 housing, 203 swash plate, 204 main shaft, 207 piston, 211 coupling member, 215 piston rod, 300 one-sided swash plate, variable capacity compressor, 302 housing, 303 journal, 304 main shaft, 307 piston, 312 piston support, 313 drive pin, 314 sleeve, 315 piston rod, 400 torque converter, 401 impeller, 401a impeller blade, 401b impeller hub, 402 stator, 403 turbine, 403a turbine blade, 403b turbine hub, 404 one-directional clutch.

【書類名】　図面　drawings

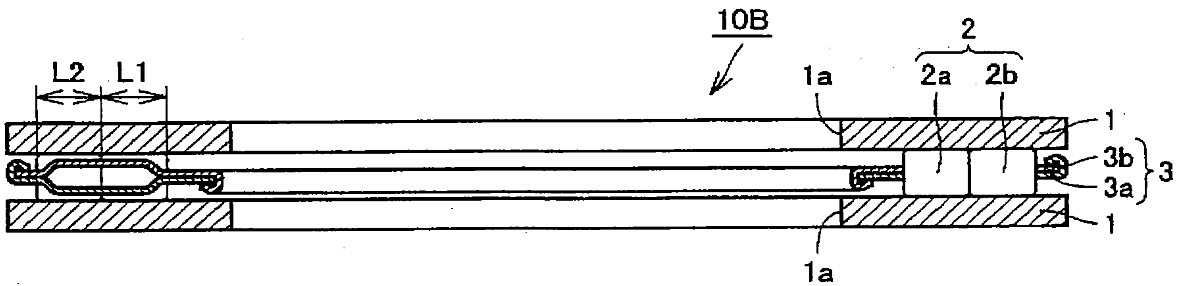
document name

【図１】

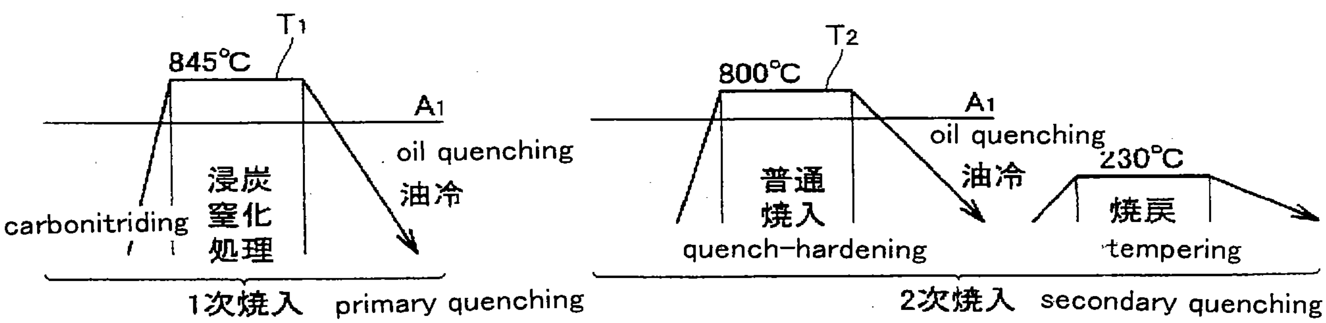
Fig. 1



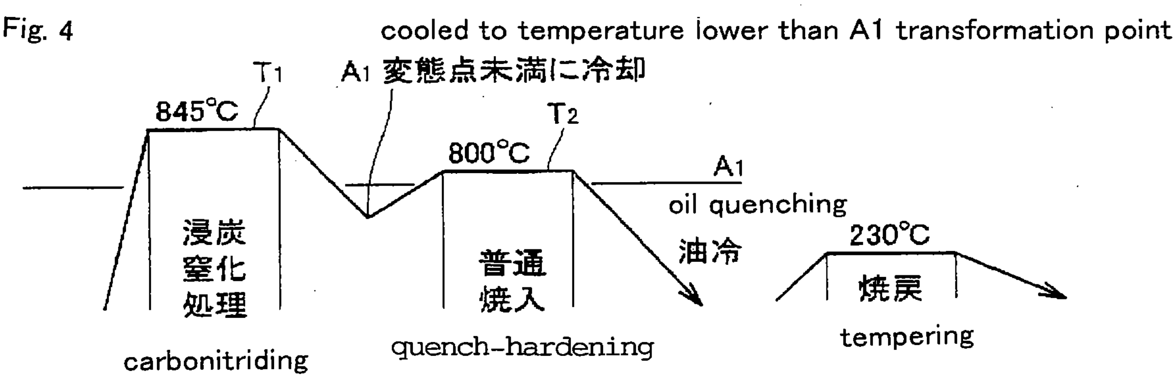
【図２】 Fig. 2



【図３】 Fig. 3

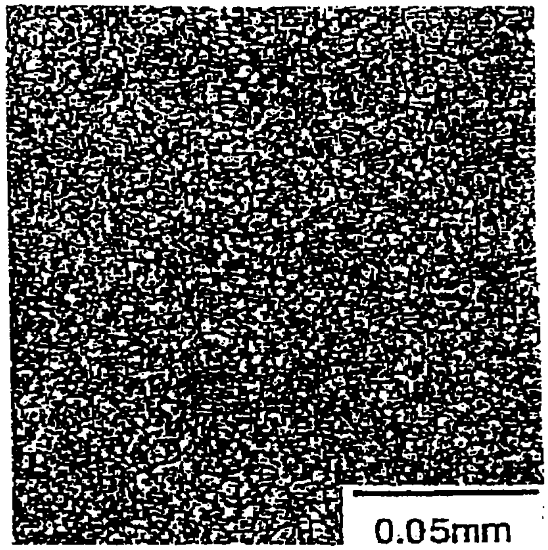


【図４】 Fig. 4

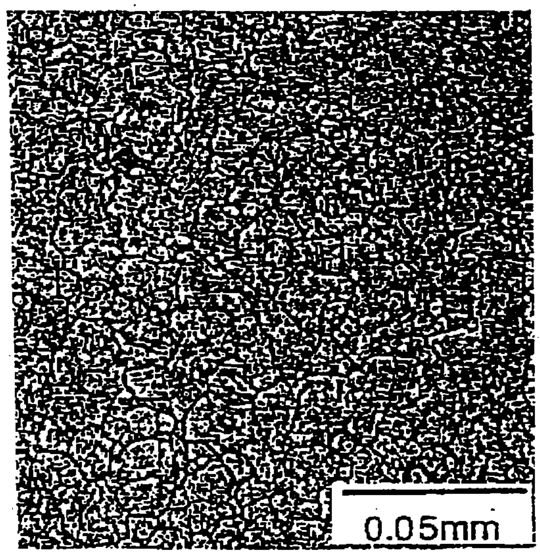


【図５】　Fig. 5

(a)

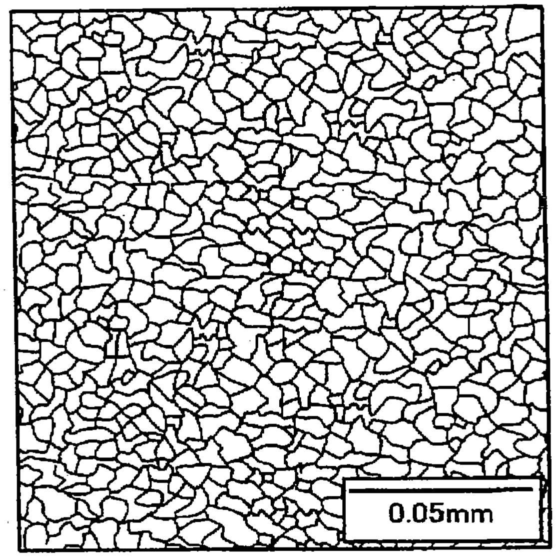


(b)



【図６】　Fig. 6

(a)



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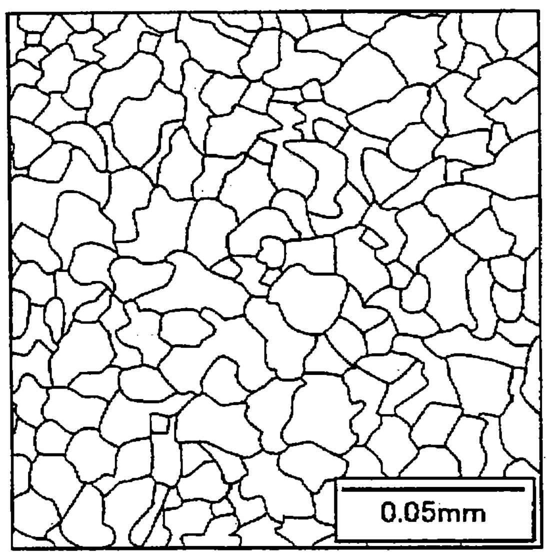
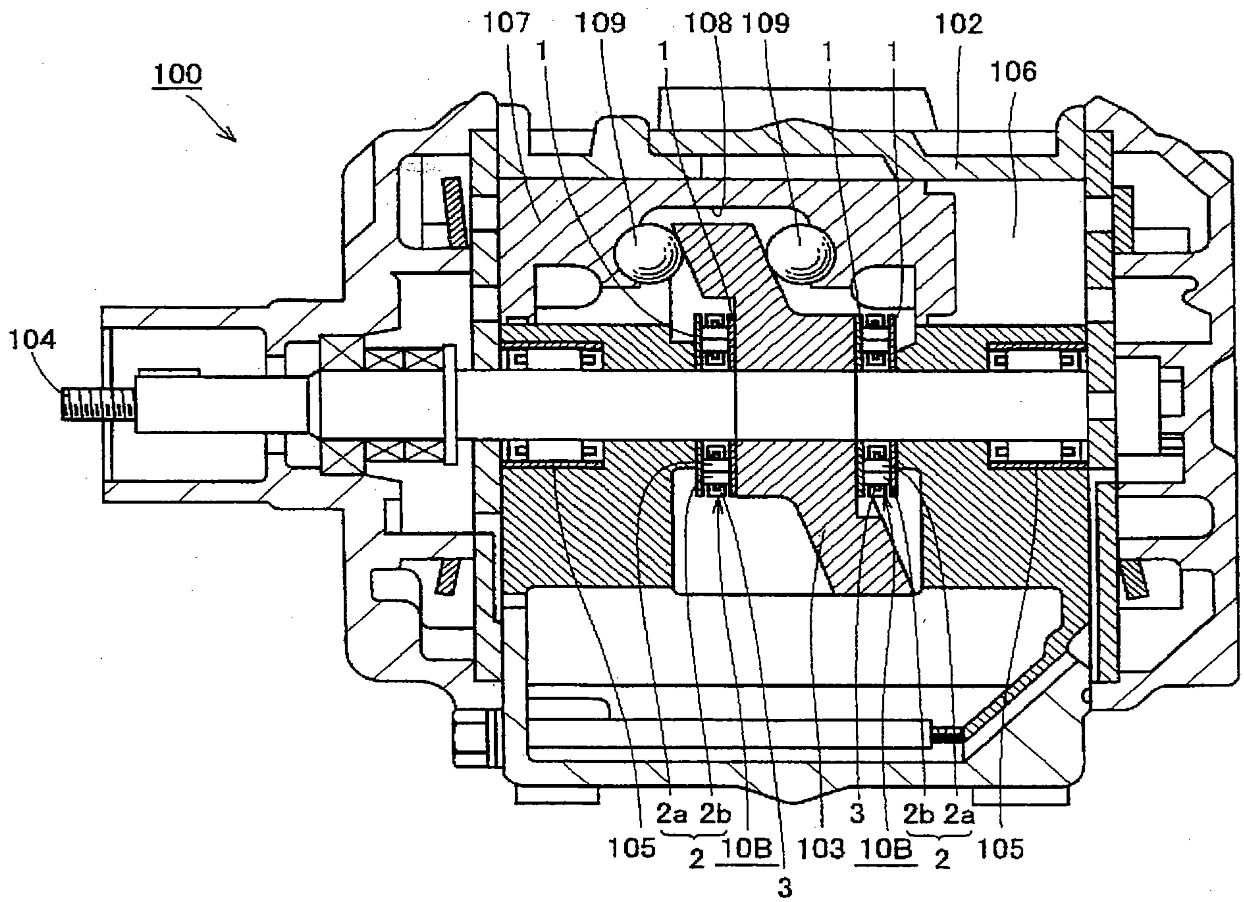


【図７】　Fig. 7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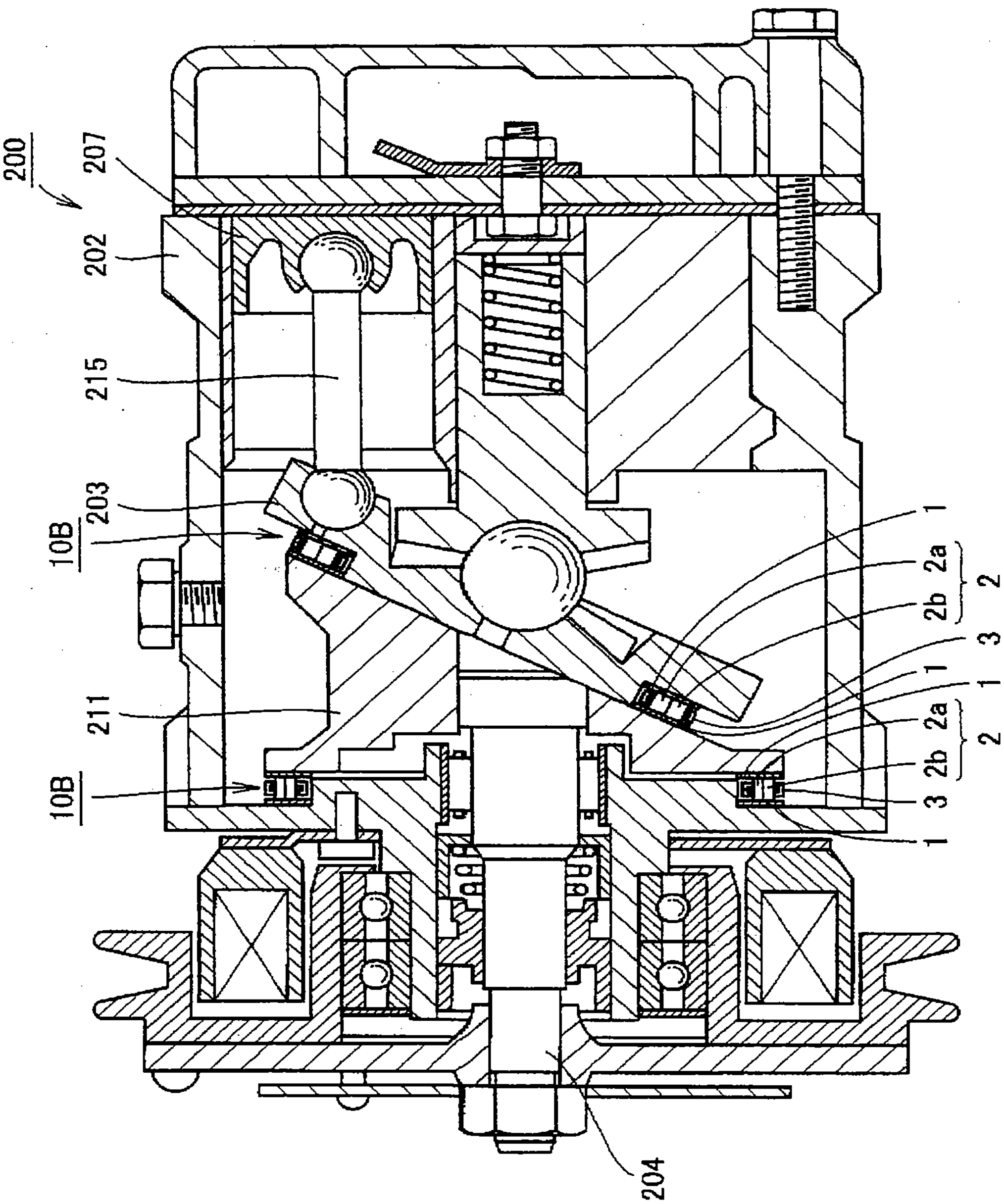
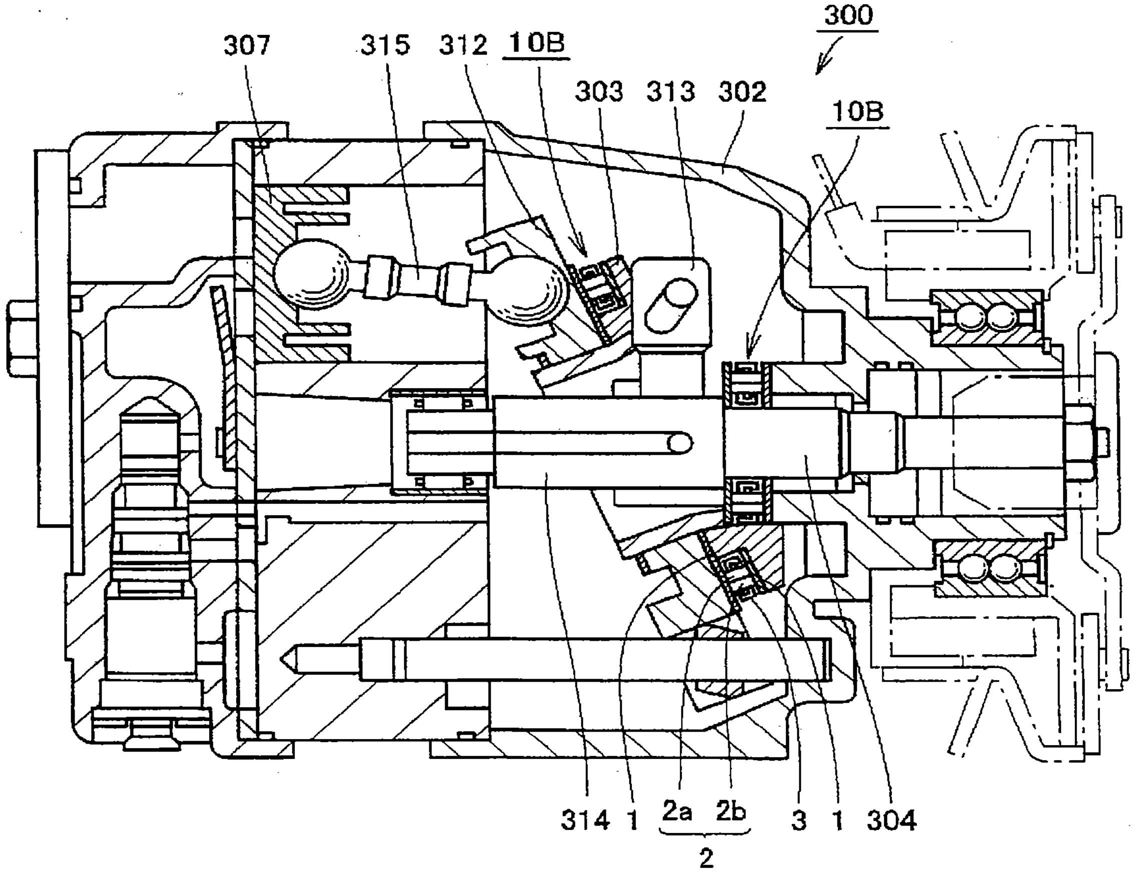
109
108
109
102
106
1
1
1
1
105
2a
2b
2
10B
3
103
3
10B
2b
2a
2
105

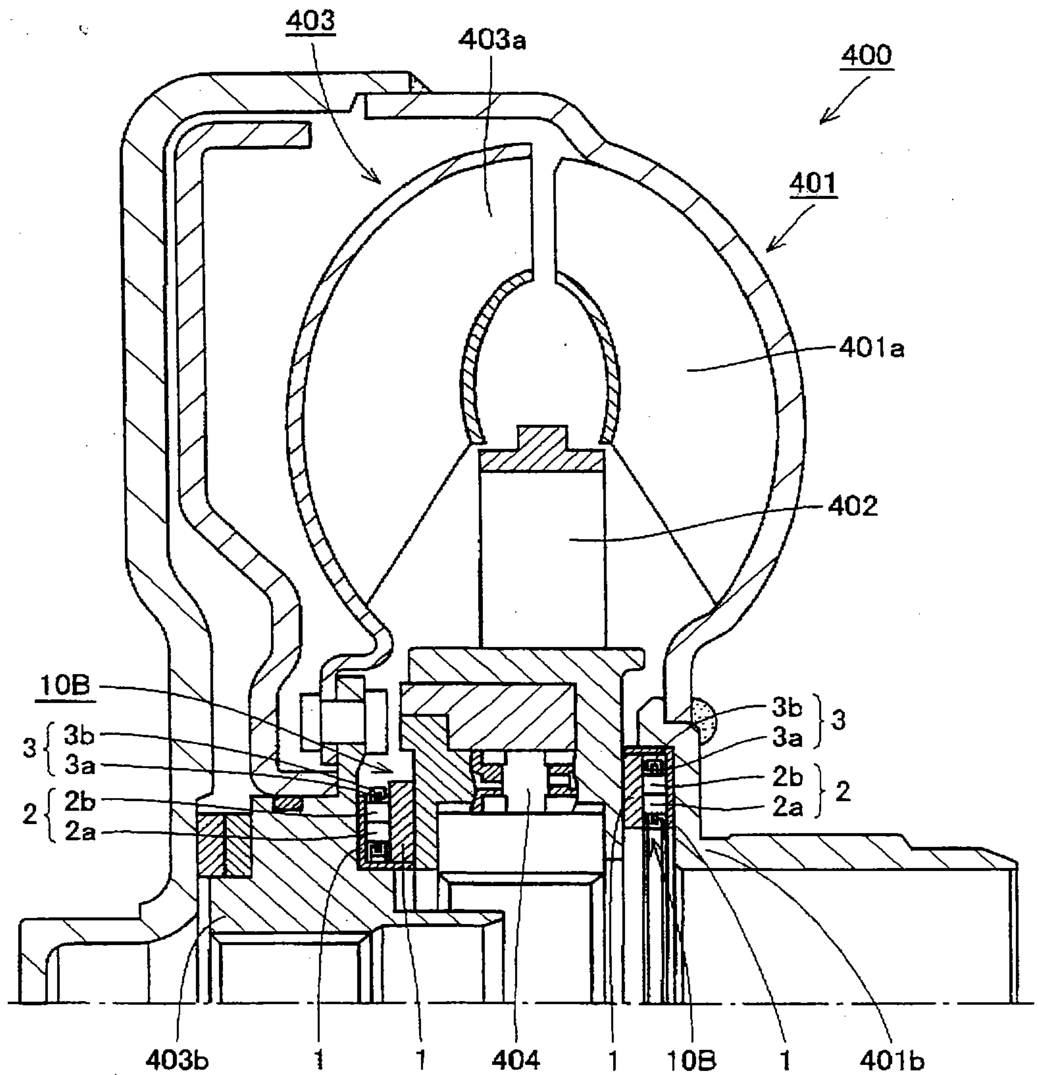
【図８】　Fig. 8



【図９】　Fig. 9



【図１０】　Fig. 10



[Document Name] Abstract

[Abstract]

[Subject] An object is to provide a long life thrust needle roller bearing resistant to an early failure caused by surface damage such as surface-originated flaking and resistant also to common load-dependent rolling contact fatigue.

[Solving Means] In a thrust needle roller bearing 10A having a washer 1 formed of a thin steel plate and a needle roller 2, at least the washer 1 has a nitrogen enriched layer at a surface layer portion, amount of retained austenite in the surface layer portion is at least 5 volume % and at most 25 volume %, and austenite grain size number of the surface layer portion is 11 or higher.

[Selected Drawing] Fig. 1